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DESIGN OF THE PEDAGOGICAL MODULE FOR AN EMOTIONALLY INTELLIGENT TUTORING SYSTEM

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Abstract. Since 1970-ties the research is being carried out for the development of intelligent tutoring systems (ITS) that are trying to imitate human-teachers and their teaching methods. However, over the last decade researchers inspired by the close relationship between emotions and learning have been working on the addition of an emotional component to human-computer interaction. This has led to creation of a new generation of intelligent tutoring systems – emotionally intelligent tutoring systems (EITS). Despite the research carried out so far, a problem how to adapt tutoring not only to a student's knowledge state but also to his/her emotional state has been disregarded. The paper presents study on how to use the determined student's emotional state further in order to change behaviour of the intelligent tutoring system looking from the pedagogical point of view and to implement this as a part of the pedagogical module. The architecture of the planned tutoring system that adapts the tutoring both to student's emotions and knowledge is also described in the paper.

Keywords: emotions, design, intelligent tutoring systems, pedagogical module.

Introduction

Nowadays, computers are an integral part of students' private, social, and professional life. With the evolvement of technologies in the educational field, people have the possibility to study at any time and place convenient for them, as well as to choose the appropriate teaching pace and amount of teaching content.

Since 1970-ties the research is being carried out for the development of intelligent tutoring systems by improving computer-aided instruction systems existed at that time. These improvements were made using techniques of artificial intelligence (AI) to provide more individualized learning process appropriate to the knowledge level and learning abilities of a particular student. Such type of systems is trying to imitate human-teachers and their teaching methods. As a result, more and more research is being conducted towards humanization of educational technologies not only from the point of view of their operation at the level of the human-teacher, but also from the point of view of their visual appearance with aim to make the learning process supported by these systems much closer to the real learning conditions.

Recent research in psychology, neuroscience, education, and cognitive science has shown that emotions play an important role in the learning process, decision making, and motivation (Ahn, Picard 2005). As a consequence, over the last decade a number of research groups inspired by this close relationship between emotions and learning have been working on the addition of an emotional component to human-computer interaction. This has led to creation of a new generation of ITSs – emotionally intelligent tutoring systems (Ochs, Frasson 2004a).

Despite the research carried out so far and the already designed EITSs, a problem how to adapt tutoring not only to a student's knowledge state but also to his/her emotional state has received much less attention. The paper presents study on how to use the determined student's emotional state further in order to change behaviour of ITSs looking from the pedagogical point of view and to implement this as a part of a pedagogical module which constitutes a component of ITSs able to imitate the human-teacher, to determine appropriate tutoring strategies, and to manage the entire learning process. The architecture of the planned EITS that adapts tutoring both to student's emotions and knowledge is also described in the paper, as well as the first step in the development of the pedagogical module is done. It is related to the design of general guidelines for the selection of tutoring strategies that take into account not only students' knowledge and learning style but also their emotions.

The structure of the paper is as follows: the general information on ITSs and their components is given; the role of emotions and EITSs are described; the design of the pedagogical module is presented and discussed.

Intelligent tutoring systems

ITSs are adaptive computer systems which are based on the theory of learning and cognition. They implement tutoring process similar to one-to-one teaching realized by human-teachers. An ITS has an ability to provide individualized tutoring process and feedback to students without the intervention of a human-tutor. The key feature of ITSs is an ability to adapt presentation of teaching materials to a particular student by using methods of AI to make pedagogical decisions and to represent information about each student (Mahdu 2011).

Learning process supported by ITSs is similar to one-to-one interaction of a student and a teacher. Therefore an effective ITS should simulate what good human-tutors do when tutoring in a one-to-one situation. Bloom (1984) has mentioned that educators should try to replicate the same strategies used by students and teachers in a one-to-one environment to other teaching situations, because the one-to-one tutoring environment is ideal for learning.

Design and development of ITSs requires involvement of researchers from different study fields because, in addition to necessary problem domain knowledge and programming skills, the expertise from teachers and psychologists is also needed to develop tutoring strategies, pedagogical module, and student model. Also it is necessary to determine students' learning characteristics that are important in the development of the student model and the pedagogical module of ITSs. One of such students' characteristics is learning style. It is found that students with different learning styles prefer different pedagogical support when learning in a one-to-one educational environment (Ally, Fahy 2002). When students are engaged in the learning process, they have many individual differences, such as unique learning styles, different motivational levels, different backgrounds, different levels of knowledge, and different expectations, as well as emotions of each student should be taken into account. The question is how to develop an ITS that identifies these individual differences and adapts accordingly the tutoring process to meet learners' individual needs. Also pedagogical knowledge of a tutor in a one-to-one situation is the least understood and does not exist in a form that can be directly included in an ITS (Ally 2005). ITSs should reason about a student's knowledge, monitor a student's solutions, and adapt tutoring strategies to the student's individual learning way, as well as it should be able to conduct its own student analysis and continually improve itself during interaction with students to become a more effective tutoring system (Woolf 1987).

ITSs usually consist of a problem domain module, a student model, a pedagogical and interface modules (Fig. 1).

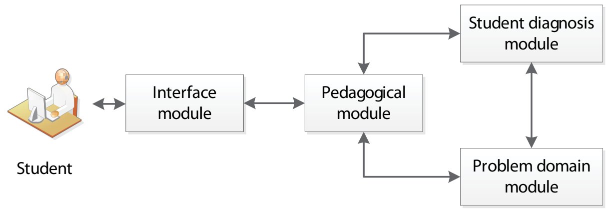

Fig. 1. The traditional architecture of ITSs

Problem domain module

To provide learning content, ITSs must have a problem domain module. It contains the domain knowledge that the system plans to teach. The domain knowledge includes both the content to be taught and the application of that knowledge to solve related tasks; therefore it can be represented in the form of declarative and procedural knowledge. The declarative knowledge mostly is related to content and represents facts, concepts, and principles and the procedural knowledge illustrates the application of the knowledge (Ally 2005).

Representation of the problem domain module is one of the important issues to be considered while designing an ITS because it should be developed in such a way that the pedagogical module could interact with this module and could select appropriate domain knowledge needed for the tutoring process. If the representation is not compatible with the pedagogical module, then the tutoring system will not be able to fulfil its functions (Sarma 2007).

Some AI methods that are used for the representation of the domain knowledge include development of semantic networks, application of production rule systems, creation of frames and concept maps, as well as development of logical statements for making inferences from facts. While a student interacts with the system, the latter forms the student model based on this interaction.

Student diagnosis module

The developed AI techniques and the increasing power of computers allow modelling a student. This enables the system to predict learning behaviour of individual students and diagnose causes of errors. The modelling process results in a student model that represents cognitive processes (information processing, analysis, synthesis, information retrieval, calculation, and problem solving), meta-cognitive strategies (learning from errors, when to access more information, when a learning outcome has been reached), and psychological attributes (developmental level, learning style, motivational level, interests, and also emotions) (Ally 2005). Ideally, the student model would be the exact copy of student's knowledge. Different machine learning techniques exist that are used to model students, e.g. Bayesian networks, artificial neural networks, rule-based models.

The student model should identify the student's learning style and preferences based on interaction with the student and should send this information to the pedagogical module which is responsible for the appropriate adaptation of tutoring activities.

Pedagogical module

The pedagogical module is the system's component that decides how and when the domain knowledge is presented to students. This module usually imitates the pedagogical approach used by human-tutors (e.g. when to present a new topic, which topic to present, when a review is needed) (Kort *et al.* 2001). An ITS should have three tutoring characteristics (Bhagat *et al.* 2002):

- control over the representation of the pedagogical knowledge for selecting and sequencing the teaching materials;
- capabilities for responding to student's questions about pedagogical goals and content;
- strategies for determining when a student needs help and for delivering the appropriate help.

Since the pedagogical module performs the same functions as a tutor in a one-to-one tutoring situation, then it interacts with the student by selecting problems to be solved, by monitoring and analyzing the student's performance, providing assistance upon a request, and selecting teaching materials that are necessary for addressing student's knowledge gaps. Teaching methods are determined on the basis of diagnostic information obtained in the student modelling process (Ally 2005). Considering the problem domain knowledge and student's current knowledge level, the pedagogical module selects the most effective way for the presentation of teaching material. By interacting with the student model, the pedagogical module decides which tutoring activities should be selected further so that the student could master the topic.

The pedagogical module should be designed in such a way that the appropriate teaching action is taken at appropriate time. For this purpose machine learning techniques, e.g. rule-based methods, Bayesian networks, or case-based reasoning are being used (Sarma 2007).

Once the appropriate tutoring strategy and the particular action are determined, they must be realized through the interface module. This module reflects the ITS in its final form – in the way how the student sees it.

Interface module

The interface module controls interaction between the student and the system. The user interface can affect the success of the ITS because when the ITS presents a topic the interface can strengthen or weaken the presentation of teaching materials. Since the interface is the final form in which the ITS presents itself, qualities such as ease of use and attractiveness could be crucial to the student's acceptance of the system. Secondly, progress in media technology is increasingly providing more and more advanced tools influencing also the ITS design (Nwana 1990). The interface module works with the pedagogical module to learn about students so that the appropriate interface elements could be adjusted for the student.

The interface can be represented in the form of graphics or text or in another form but it will mostly depend on the learning style of the student. The system should be able to infer the most appropriate interface for a student based on information provided by the student, the student learning style, and inferences made about the student (Ally 2005).

Emotions and emotionally intelligent tutoring systems

Research in neurosciences and psychology has shown that emotions influence various behavioural and cognitive processes, such as attention, long-term memorizing, decision-making, etc. (Chaffar, Frasson 2004). People often separate emotions from logical thinking, believing that emotions are an obstacle in rational decision making. However, recent research has shown that in every case the cognitive processes, for instance decision making, of an individual are strongly dependent on emotions. An important special case of a cognitive process is the learning process. Learning requires fulfilling a variety of tasks such as understanding, memorizing, analyzing, reasoning, or knowledge applying (Ochs, Frasson 2004b).

Traditionally emotions have been viewed as a source of motivational energy, but they are often not regarded as an independent factor in learning or motivation. However, the motivation to learn is closely related to learner's success or failure in the learning process. Emotional states of the student can influence his/her problem solving abilities and even affect desire to engage in the learning process and motivation to learn (Vesterinen 2001; Matuliauskaitė, Žemeckytė 2011). When people become motivated to act, both thinking and learning are enhanced and the ability to acquire new knowledge is increased; when perceived information is interpreted as negative, thinking and learning can be hindered (Lawson 2013).

At the time when interest to the relationship between emotions and learning started to grow, there was a lack of a comprehensive and confirmed emotion theory that would be focused on learning and explained which emotions are the most important in the learning process or how they can affect student's learning abilities (Picard *et al.* 2004). Until then, emotion theories were searched in psychology and they mostly defined the relationship between emotions and cognition in general. As a result, over the last decade research that was focused on emotions in the learning process increased. Moreover, a number of theories that directly describe the relationship between emotions and learning appeared (D'Mello, Calvo 2012) – cognitive disequilibrium theory (Lagud, Rodrigo 2010), control–value theory (Pekrun 2006), academic risk theory (Meyer, Turner 2006), flow theory (Lagud, Rodrigo 2010) and other theories on emotions and learning (Weiner 1985; Zeidner 2007). These theories suggest that emotional states such as confusion, curiosity, interest, flow, joy, boredom, frustration, and surprise have become particularly relevant in learning and can influence student's performance during learning. Most of these emotions could be found in the learning process implemented both by ITSs and by human-teachers (D'Mello, Calvo 2012).

Teaching and learning are emotional processes: a teacher who communicates the content in an emotional way will be more successful than another who behaves and communicates unemotionally (Ochs, Frasson 2004b). Also ITSs of the latest generation should be able to influence students' emotions in similar way as human-teachers affect them in order to improve students' learning abilities. Recent scientists' attention to the research on the emotional impact on humans has led to a new branch of AI called "Affective Computing" that deals with design of systems and devices that would be able to recognize, explain, and process human emotions (Picard 1997). Also a new concept related to ITSs appeared – EITSs (Ochs, Frasson 2004a). Another name used for these systems is affective tutoring systems (Alexander, Sarrafzadeh 2006).

EITS are capable to act as traditional ITSs and to implement all components of the learning process (choose the way to present teaching material, adapt teaching pace to student's learning abilities, give hints during solving of tasks, provide appropriate feedback after tasks and knowledge assessment, modify content, amount, and complexity of teaching material) and also to adapt them to an emotional state of the student and to show its own emotions; thus, reacting to student's actions in the environment. Developing such tutoring systems, particular attention should be paid to the adaptation of tutoring process and tutoring strategies taking into account not only the student's current knowledge state but also his/her learning style and emotional state.

EITSs would never be able to respond to a student's emotional state, if they were unable to determine his/her emotional state. Consequently, most of the current research in this area are directed to determination of the student's emotional state on the basis of facial features (D'Mello *et al.* 2010), body language (D'Mello, Graesser 2009), physiological signals, e.g. skin conductance or heart rate (Chaffar, Frasson 2010), and speech (Forbes-Riley *et al.* 2008).

An EITS can be endowed also with the ability to show its own emotions using animated pedagogical agents that have capabilities to express emotions (Sarrafzadeh *et al.* 2008). Such characteristics as facial expressions, gestures, and understanding of human emotions together with the ability to communicate make them more attractive to students because agents provide more natural interaction – similar to the interaction between a student and a human-teacher. If a tutoring system can determine an emotional state of the student and the pedagogical agent can appropriately react to it through pedagogical actions, then there is a high probability that the student will be more involved in the learning process and will feel less loaded during task solving (Mao, Li 2010). Currently, pedagogical agents in educational systems mostly are used to provide emotional and motivational feedback, as well as to increase the credibility of the system and its effectiveness.

Development of the pedagogical module

Today tutoring systems that are able to recognize and respond to students' emotional states are already a reality, for example, *Affective AutoTutor* (D'Mello, Graesser 2012), *Affective Learning Companion* (Burleson 2006), *ITSPOKE* (Forbes-Riley *et al.* 2008), *Easy with Eve* (Sarrafzadeh *et al.* 2008), *Wayang Outpost* (Woolf *et al.* 2007). However, regardless of the research carried out so far and the already developed EITSs, much attention has been devoted to detection and classification of student's emotions. Thus, a problem how to adapt tutoring not only to a student's knowledge state but also to his/her emotional state has been disregarded (Chaffar, Frasson 2010; D'Mello, Calvo 2012). This actually is the other equally important direction in development of EITSs.

Studying literature several possible reasons why emotional aspect is taken into account so little in the adaptation of tutoring can be inferred:

– acquisition of tutoring knowledge is a complex and time consuming process even without inclusion of emotions in this knowledge;
– much attention has been devoted to the determination and modelling of student's emotional states;
– little research has been carried out to examine one-to-one tutoring, especially conditions under which different tutoring strategies may be used and their impact on learning outcomes (mostly research on influence of positive/negative feedback on the learning process has been done);
– adaptation of tutoring to students' emotions is a complex task with a high degree of uncertainty because various attributes of the tutoring process (student's knowledge and previously acquired skills, student's abilities, learning goals, student's emotions, progress on the tutorial task, tutor's domain knowledge and pedagogical objectives, conversation history, etc.) must be considered not only emotions (Blanchard *et al.* 2009; Chaouachi, Frasson 2012);
– both the identification of student's states (cognitive, meta-cognitive, and emotional) and reasoning procedure for making optimal pedagogical decisions have become more complex (Bourdeau, Grandbastien 2010) because situations may arise in which a tutoring system is not confident of how to provide an appropriate emotional support and what will be the consequence of a possible tutoring action on the emotional state of the student and his/her further learning (Robison *et al.* 2010).

Since the adaptation of the tutoring to student's emotions is a critical aspect for EITSs, then it is important to carry out research on how to use the determined emotional state further in order to change behavior of the tutoring system looking from the pedagogical point of view and implement this as a part of the pedagogical module. As it was previously mentioned, this component imitates the human-teacher and determines appropriate tutoring strategies, adapts the tutoring process depending on the curriculum, student's cognitive needs, emotions, and abilities.

The proposed architecture of the EITS

The overall architecture of the planned EITS is designed before the development of the pedagogical module to understand in which areas it is necessary to make additional studies and what kind of changes will be necessary to introduce in other components of the ITS so that pedagogical module could fully function and adapt tutoring process to student's emotions, learning style, and knowledge.

The proposed architecture of the EITS is represented in Fig. 2 on the following page.

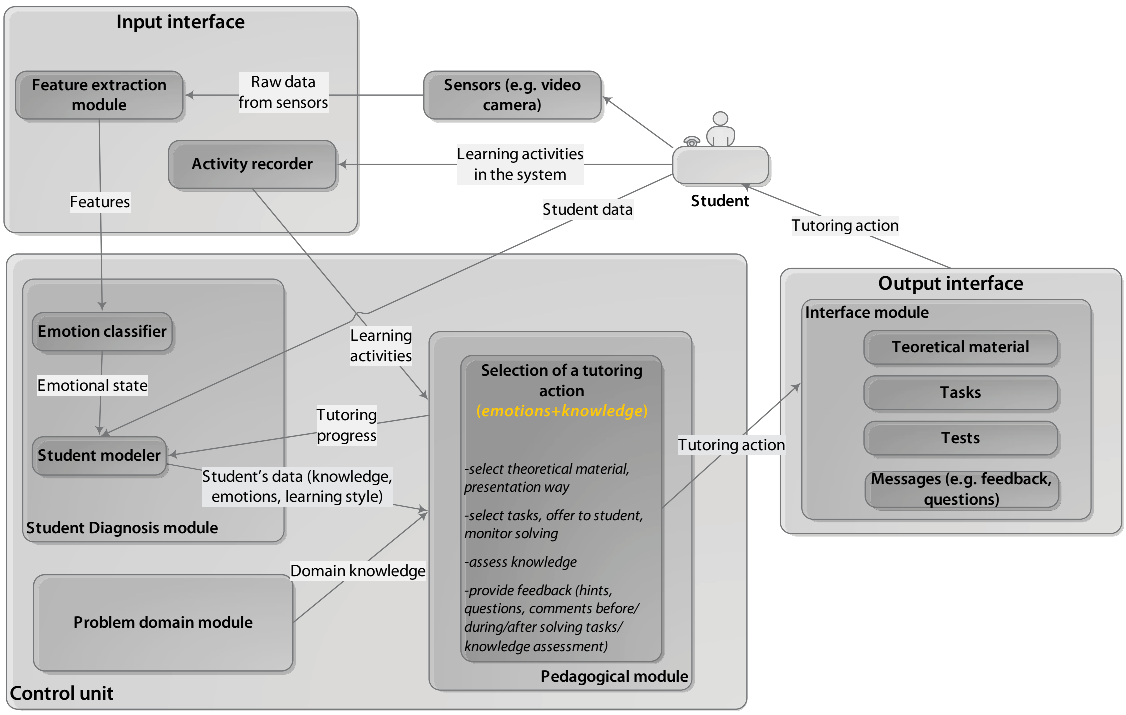

Fig. 2. The overall architecture of the proposed EITS

Sensors (e.g. video camera) are used to receive information about the student from the external environment as raw data (video or image) that is further sent to a *Feature extraction module*. This module extracts from these data features required for the determination of the student's emotional state. In case of a video camera, the features can be shape of eyes and eyebrows, as well as shape of mouth and displacement of lip corners. Then, the extracted features are sent to the *Emotion classifier* which on the basis of the received features and their values makes prediction of an emotional state that is sent to the *Student modeler*. This component interacts with the *Pedagogical module* by sending data about the student – his/her knowledge level, learning style, and emotions. The *Pedagogical module* considering the information received from the *Student modeler*, the *Problem domain module*, and the *Activity recorder* (it registers student's actions and input data during such activities as task solving or mastering theoretical material) provides adapted tutoring by selecting the most appropriate tutoring action. The selected tutoring action that mostly depends on the chosen tutoring strategy further is provided to the student through the *Interface module*.

Since the main emphasis of the research is placed exactly on the development of the pedagogical module then the next part of the paper describes the preliminary design phase of the pedagogical module.

Preliminary design of the pedagogical module

As the selection of a tutoring strategy is the main goal of the pedagogical module, then the first step of the development of the pedagogical module is related particularly to the design of general guidelines for selection of tutoring strategies that take into account not only students' knowledge and learning style but also their emotions. Tutoring strategies are a tutor's primary tool for controlling the flow of a lesson and student's progress (Porayska-Pomsta, Pain 2004). These strategies allow influencing emotions in order to improve student's performance and learning outcomes, as well as each strategy determines the next action that will be provided to the student. Part of this step included examination of the previously mentioned theories (cognitive disequilibrium theory, control–value theory, academic risk theory, flow theory, test anxiety theory, attribution theory, etc.) and approaches (FEASP (F(ear) E(nvy) A(nger) S(ympathy) P(leasure) (Astleitner 2000) and ECOLE (Emotional and Cognitive Aspects of Learning) (Glaser-Zikuda *et al.* 2005).

Most strategies, regardless of their complexity, are based on a fundamental three-step process: teach (presentation of material), practice (exercises or applied scenarios), and test (feedback through assessments) (Miles 2003). Therefore, guidelines are divided into several categories representing the tutoring process as a whole and three fundamental steps (teach, practice, and test) underlying all tutoring strategies. The developed guidelines are as follows.

A. The tutoring process as a whole:

- the tutoring process and course materials should be clearly structured (this positively influences interest and motivation and reduces the likelihood of boredom and anxiety);
- feedback after tasks or knowledge assessment should be appropriate to the student's knowledge, it should encourage not to give up in case of mistakes. First of all, it should highlight the acquired knowledge and skills and correctly solved tasks, thus showing student's strengths and then point to poorly mastered concepts, topics, or tasks, and it should suggest what should be done to address these gaps in knowledge (this increases motivation and reduces the likelihood of anxiety);
- the tutoring process should be more detail-oriented in situations when gaps in student's knowledge are found (this reduces the likelihood of frustration and anxiety).

B. Teach step:

- theoretical part should be structured and sequential – it should reflect how topics are related to each other (this positively influences interest, engagement, and motivation and reduces the likelihood of boredom);
- give students an opportunity to select topics by themselves (this positively influences engagement, interest, and motivation);
- use humour by showing humorous interpretations of content (e.g. viewing something in an unusual perspective) or creating humorous comics illustrating a certain part of content (this positively influences enjoyment and reduces the likelihood of boredom).

C. Practice step:

- tasks must have a value looking from student's point of view; it should be meaningful for the student (this increases interest and motivation and reduces the likelihood of boredom);
- students should be given the opportunity to choose the level of difficulty for tasks or the tutoring system should offer tasks with a difficulty level that is consistent with the student's knowledge or is a little higher; thus creating a challenge for the

student's abilities, and at the same time, causing activity-enhancing emotions such as interest or confusion and reducing the likelihood of boredom;
- give students an opportunity to select tasks by themselves (this increases engagement and interest);
- demonstrate how one problem can be solved in different ways if it is possible (this reduces the likelihood of frustration);
- use tasks similar to those that will be used in the knowledge assessment in order to timely prepare students for tests; thus decreasing anxiety and improving students' confidence in their own abilities;
- use game-like activities and tasks (this positively influences engagement, interest, and motivation and reduces the likelihood of anxiety);
- provide students with self-assessment opportunities (this increases engagement and motivation and reduces the likelihood of anxiety).

D. Test step:
- show the student's progress, thus creating a willingness to strive for something higher (this increases interest and motivation and reduces the likelihood of anxiety);
- during testing, use also multiple-choice tasks because open-ended tasks require more intense usage of memory (this reduces the likelihood of anxiety).

Conclusions

The concepts of ITSs and EITSs are described in this paper as well as the role of emotions in the learning process is explained. The already developed EITSs were studied to determine their capabilities to adapt tutoring not only to the student's current knowledge state but also to his/her emotional state and to identify problems related to the tutoring adaptation. Based on this study the overall architecture of the planned EITS was designed and the preliminary design phase of the pedagogical module was described. Initial general guidelines were developed on how to select tutoring strategies to influence and regulate student's emotions during the learning process. However, it is planned to improve these guidelines so that they could be used in the development of the pedagogical module.

Future research of the paper's author will be focused on the development of the prototype of the pedagogical module that will adapt tutoring strategies to determined and modeled student's emotions and knowledge. The realization of this task will require also the development of the student model that includes student's personal data, knowledge level, and emotional state and development of the pedagogical module that selects tutoring strategies based on a tutoring situation, student's knowledge, and emotions. Since the latter task will involve decision making under conditions of uncertainty because of changing tutoring situations, student's knowledge, and emotions, a study and application of AI knowledge representation and reasoning methods using uncertainty (e.g. influence diagrams) is planned.

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PEDAGOGINIO MODULIO EMOCIJAS SUPRANTANČIAI MOKYMO SISTEMAI KŪRIMAS

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Santrauka

Straipsnyje nagrinėjami klausimai, susiję su informacijos apie nustatytą studento emocinę būklę taikymu sumaniosios mokymo sistemos elgsenai keisti, taip pat emocinės būklės poveikis mokymo procesui pedagoginiu požiūriu. Siūlomas pedagoginiams aspektams įgyvendinti specializuotas informacinės sistemos modulis. Parodoma pedagoginio modulio vieta sumaniosios mokymo sistemos, pritaikančios mokymo procesą konkretaus studento žinių ir emociniam lygmenims, architektūroje.

Reikšminiai žodžiai: emocijos, kūrimas, intelektinė mokymo sistema, pedagoginis modulis.